M.O. 514 AIR MINISTRY

METEOROLOGICAL OFFICE

THE METEOROLOGICAL MAGAZINE

VOL. 78. NO. 928. OCTOBER, 1949.

WEATHER FORECASTS BY TELEVISION

By E. G. BILHAM, B.Sc., D.I.C.

On the evening of July 29 television viewers in Great Britain were able to see and hear a new feature in the programme broadcast from Alexandra Palace, namely a weather report and forecast illustrated by charts. This feature has since been included as the last item of the television programme each evening.

The weather report begins with a brief summary of the weather of the day, illustrated by a chart (see Fig. 1, p. 278) headed "Weather this evening" showing in a very generalised sort of way the weather over the British Isles at 5 p.m. This is followed after a brief pause by a second chart (Fig. 2), headed "Weather expected to-morrow morning", with spoken text indicating the main features of next day's weather over the country as a whole. Next follows a more detailed forecast for London and south-east England covering the period 8 a.m. to midnight. The report concludes with a "Further Outlook" for London and south-east England. The actual text of the spoken script which accompanied the charts on July 29 (the Friday preceding August Bank Holiday) was as follows :—

Television Forecast, Friday, July 29, 1949

Here is the Meteorological Office weather report and forecast. The first chart shows the general weather situation this evening.

A north-westerly air stream covers the British Isles. Weather is fine generally apart from scattered showers in Scotland and northern England. It has been fine all day in the south-eastern districts of England, where temperature has exceeded 70 degrees. In northern and western districts there have been bright intervals and scattered showers.

By tomorrow morning the weather chart is expected to look like this.

It will be fine over the whole country in the morning, and the fine weather will last all day in most districts. Rain moving east from the Atlantic will reach Ireland and west Scotland during the afternoon or evening.

Here is the forecast for London and south-east England for to-morrow, 8 a.m. to midnight:—

Fair and rather warm, with afternoon temperature 75 degrees or slightly higher.

Finally, here is the outlook for London and south-east England for Sunday and Monday.

Occasional rain on Sunday but perhaps only in small amounts. Bright intervals on Monday with a cool breeze. A chance of a few showers in the afternoon and evening.

The planning of this television feature gave rise to a number of problems. The first trials showed that it was quite impossible to televise successfully

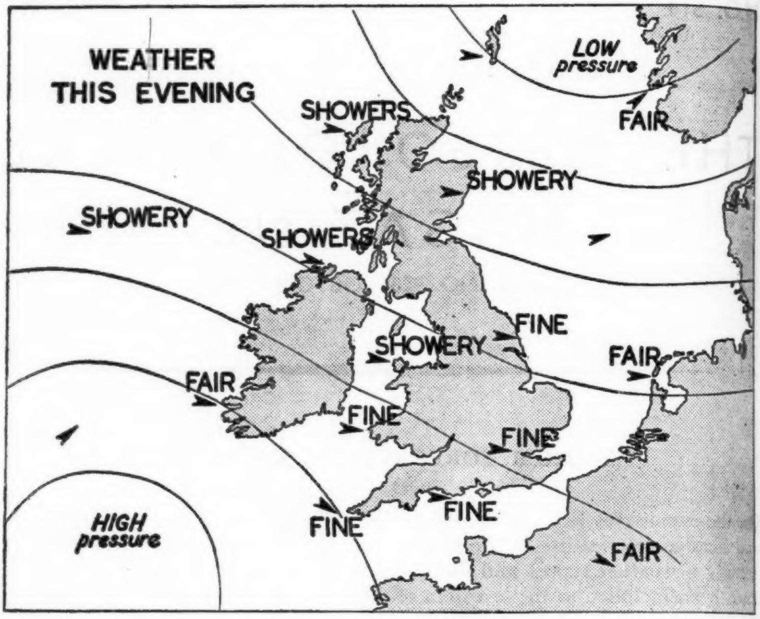


FIG. 1—FIRST CHART FRIDAY, JULY 29TH, 1949, 5 P.M.

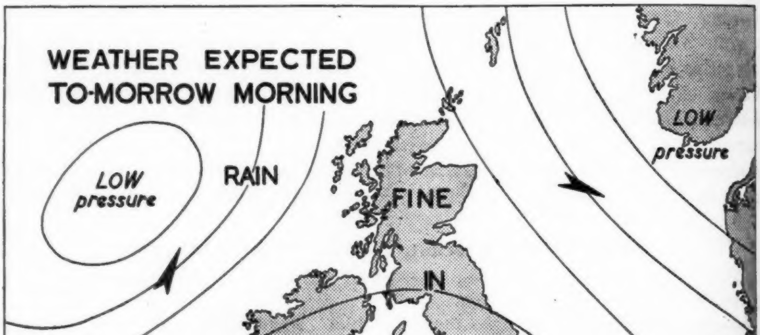


FIG. 2—SECOND CHART FRIDAY, JULY 29TH, 1949.

anything resembling an ordinary synoptic chart with the usual plottings of wind, weather and temperature. It was essential that the viewer should be able to take in, without effort, what he saw on the screen, and he could not be expected to memorise symbols or to strain his eyes by trying to read small lettering or figures. After several trials it became manifest that the sort of chart required was one in which the main weather features over relatively large areas were indicated by boldly printed legends without attempting to indicate small local variations. In the charts as now televised the weather legends are in half-inch block lettering. Wind directions are shown by very bold arrows, and the strength of the wind is roughly indicated by using a long arrow for winds of Beaufort force 6 or more and a shorter arrow for force 5 or less. Isobars are shown at intervals of 4 mb. and italic lettering is used to indicate centres of high and low pressure. Land areas are distinguished from sea areas by tinting the former in a carefully selected shade of light grey.

For technical reasons black lines on a white background do not televise satisfactorily, and paper is unsuitable because it tends to bend and cockle under the heat of the illuminating lamps. The charts used are therefore specially printed on light grey cardboard. As a further example of the technical complications it may be mentioned that this short item, lasting only two or three minutes, necessitates the use of three television cameras, one for the announcer and one for each of the two charts.

As an introduction to the series Dr. J. M. Stagg gave a short talk, illustrated with charts in which he explained the main weather features associated with high and low pressure systems, and how forecasting depends primarily on estimating the movements and developments of these systems.

TEMPERATURE FORECASTS FOR THE BRITISH ISLES

The general weather forecasts for the British Isles, which are supplied to the Press and the B.B.C. by the Meteorological Office as a daily routine, lay some emphasis on the level of temperature likely to be experienced. This information is of particular interest and importance when conditions favour frost in winter or spring, and almost equally so when very warm or hot weather is anticipated in summer.

The degree of warmth or cold expected is expressed by the use of descriptive terms, or by specifying the actual temperature likely to occur, or by a combination of the two methods. When the method of giving actual values is adopted it is usual either to specify a range of, say, 5 degrees, to indicate the general level of temperature expected (*e.g.* temperatures will be between 55 and 60°F.) or to state the value expected to be reached (*e.g.* temperatures will reach 60°F. in the London area).

When descriptive terms are employed they are selected from the following :—

hot, warm, mild, cool, cold

qualified as necessary by " rather " or " very ". The expression " normal for the time of year " is also used. These descriptive terms are defined in relation solely to the normal temperature for the time of year, no account being taken of any other meteorological factor such as the wind strength, or the humidity, which may subjectively influence the particular sensation of warmth or coldness experienced by an individual exposed to a specified air temperature.

The graduation of terms from that signifying the highest values above the normal to that signifying the lowest values below, for each season of the year, together with the associated departures from normal, is as follows :—

(*a*) *Summer—mid May to mid September*

Term	Relation of temperature to normal °F.
Very hot	More than 20° above normal
Hot	16—20° above
Very warm	11—15° above
Warm	6—10° above
Rather warm	3—5° above
Normal	2° above to 2° below normal
Rather cool	3—5° below
Cool	6—9° below
Very cool	10—15° below
Cold	More than 15° below normal

(*b*) *Spring—mid March to mid May,*
Autumn—mid September to October 31

Term	Relation of temperature to normal °F.
Very warm	More than 12° above normal
Warm	8—12° above
Rather warm	3—7° above
Normal	2° above to 2° below normal
Rather cold	3—7° below
Cold	8—15° below
Very cold	More than 15° below normal

(*c*) *Winter—November* 1 *to mid March*

Term	Relation of temperature to normal °F.
Very mild	More than 10° above normal
Mild	3—9° above
Normal	2° above to 2° below normal
Rather cold	3—5° below
Cold	6—10° below
Very cold	More than 10° below normal

When a comparison is being made between temperature conditions expected and those recently experienced, terms such as colder, cooler, milder, warmer, are employed.

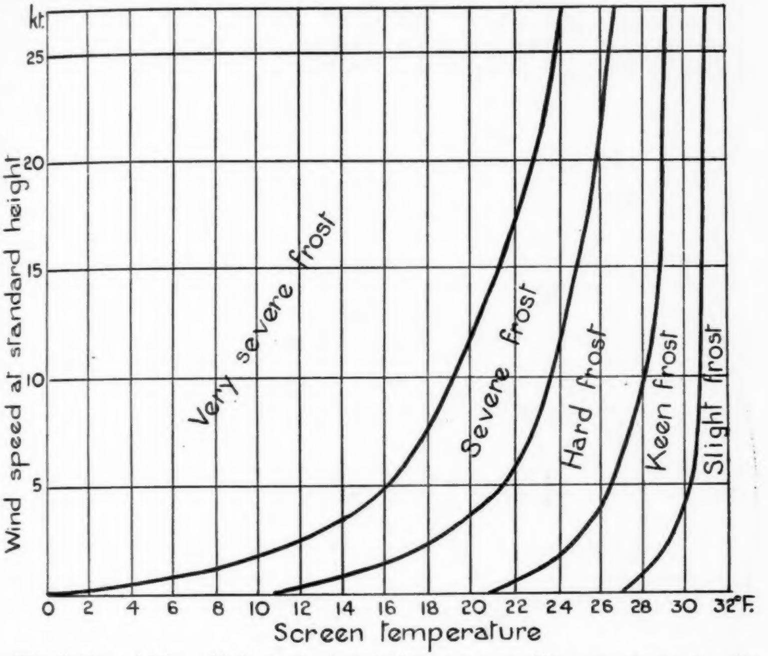
Certain special conditions of temperature and humidity are implied by the terms close, muggy and raw, and these are used, when appropriate, with the following meanings :—

close = temperature normal or above normal for the season, with high humidity, a cloudy or overcast sky, and a calm or light wind ; oppressive.

muggy = warm and damp but not necessarily oppressive.

raw = cold and damp, sometimes with fog.

For frost forecasting a special set of descriptive terms is employed. The relationship between these terms and the expected temperature involves the strength of the wind, in view of the much more damaging effect of low air temperatures or frost with strong winds than with light winds or calms. The classification is shown in the diagram.



The limits within which each descriptive term applies are shown by the curved lines. The values corresponding to calm air and to a wind speed of 20 kt. are given in the table below.

Term	Corresponding screen temperature Calm air °F.	Corresponding screen temperature Wind speed 20 kt. °F.
Slight frost	32—27	32—31
Keen frost	26—21	30—29
Hard frost	20—11	28—26
Severe frost	10— 0	25—23
Very severe frost	Below 0	Below 23

For other wind speeds the appropriate term is derived by plotting the point corresponding to the forecast temperature and wind speed on the diagram.

The term " sharp frost " is not included in the classification. It is normally used only in connexion with night frost and low grass-minimum temperatures (below 25°F.) and generally with clear skies. The screen temperature is not generally very low. A screen temperature of 30°F. and a grass minimum of 18°F. would be termed a sharp frost and the correct description of these conditions is " sharp ground frost with slight air frost ".

HALO PHENOMENA OF JULY 20, 1949

E. W. BARLOW B.Sc.

About 1030 B.S.T. on July 20, Mr. E. V. Newnham noticed that halo phenomena were in evidence and some members of the staff of the Meteorological Office at Harrow went on to the roof to view the display, which lasted till about 1100. The phenomena seen were the halo of 22°, the two mock suns of 22°, very vividly coloured, a large part of the mock sun ring (parhelic circle) and two white mock suns on this ring, as shown in Fig. 1.

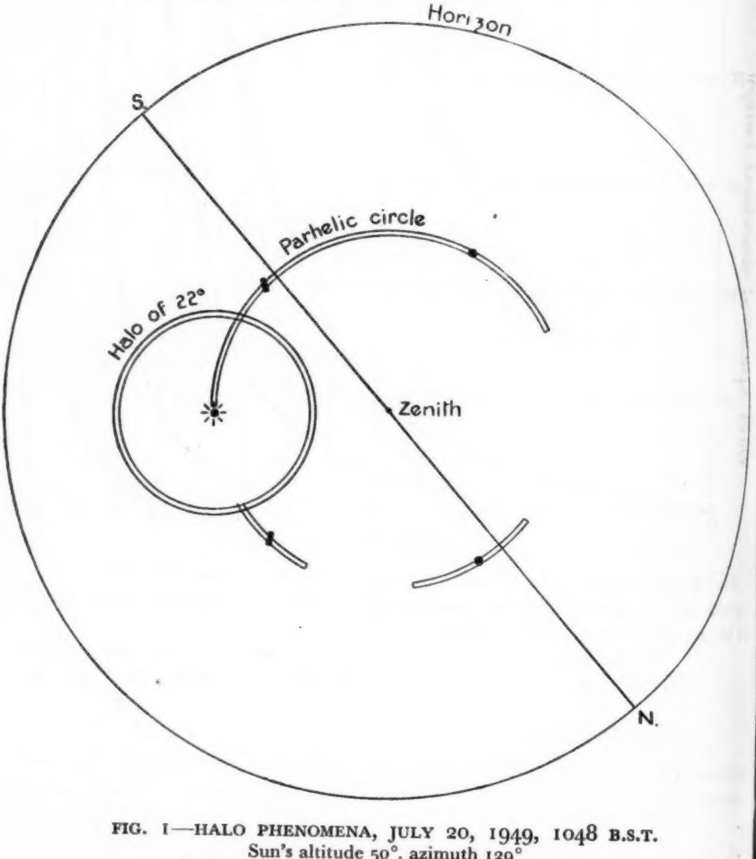


FIG. 1—HALO PHENOMENA, JULY 20, 1949, 1048 B.S.T.
Sun's altitude 50°, azimuth 129°
Four mock suns are shown on the parhelic circle

The sky was most favourable for halo production on the west side of the sun, with a very uniform veil of cirrostratus, so thin that the blue of the sky was hardly dimmed, and the bright white western part of the parhelic circle stood out in strong contrast. Some very delicate threads of cirrus were superimposed and these crossed the parhelic circle almost vertically. Elsewhere, the cirrostratus was thicker or altocumulus was present. The halo complex afforded some points of special interest.

Halo of 22°.—During the period of my own observation, from 1040 to 1100, this, the "common halo", was the least persistent and striking of all. I never saw it complete at any one time ; it was rather faint and was narrower than usual, but with more evidence of colour than it generally has. The arc of upper contact was not seen.

Parhelia of 22°.—The sun's altitude being 50°, the parhelia were about 10° distant from the halo of 22°. They presented a very remarkable aspect. In all my many previous observations of mock suns I have never seen anything approaching the brilliancy and purity of colour shown on this occasion. The colours were almost of spectrum purity, a quality which the circumzenithal arc, alone of all halo phenomena, normally exhibits. The blue end of the spectrum, which is rarely seen at all in a mock sun, was very clear. Furthermore the purity of colour, implying an absence of overlapping images, resulted in each mock sun being much smaller than usual, and instead of the normal rounded form each was oblong in shape, with the length of the oblong inclined at about 45° to the parhelic circle, as shown in Fig. 1. It might perhaps be claimed that the linear projections of the mock sun outside the parhelic circle were the beginnings of the very rare arcs of Lowitz. For a short time the western parhelion developed the well known brilliant white tail along the parhelic circle ; this soon faded, without any change in the general intensity of the parhelic circle. The eastern parhelion showed the same vivid colour as the western one, and the same shape and inclination, but was often partly obscured by cloud variation.

Parhelic circle.—This was very luminous, with very sharp edges ; it usually appears more or less diffuse. It passed through the western side of the halo of 22° right up to the sun : more frequently this part of the circle is absent. The part opposite the sun and most of the eastern side were not seen at all.

Paranthelia of 120° (*sometimes called parhelia*).—The contrast between the brightly coloured oblong parhelion of 22° and the bright white round one further along the parhelic circle was very spectacular. A rough estimate of the distance between the two, compared to the known distance of the parhelion of 22° from the sun, placed the paranthelion as about 120° in azimuth from the sun, as measured round the parhelic circle. Mock suns in approximately this position, on either side of the sun, have not infrequently been seen by various observers. For a short time Mr. Newnham and myself saw a short segment of the eastern side of the parhelic circle, with a paranthelion in the middle. This was relatively faint, the cloud being so thick that one would not have expected to see any halo phenomenon on it. The paranthelion was at the same distance from the sun as the western one, as nearly as could be judged.

Mr. D. F. Bowering, at Croydon Airport, saw the halo and parhelia of 22° and the parhelic circle.

Mr. W. Holt, at St. Chads Secondary Boys' School, Tilbury, Essex, saw the same phenomena as those visible at Harrow. In a letter to the Meteorological Office, he states that a rippling movement was seen to pass over the parhelic circle a number of times. At times the rippling movement passed over the whole of the circle, as shown in Fig. 2. At other times the ripples travelled round the circle itself, as shown in Fig. 3. This movement was also seen in the opposite direction. This is a very remarkable observation, of which it is difficult to find an explanation, since the only instances of the rippling of halo phenomena

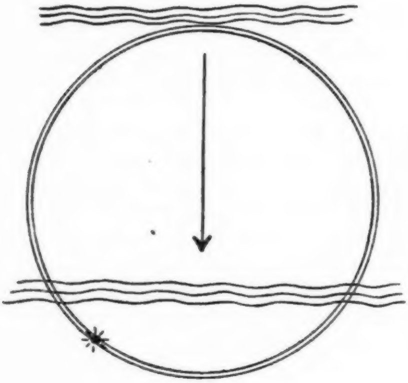


FIG. 2

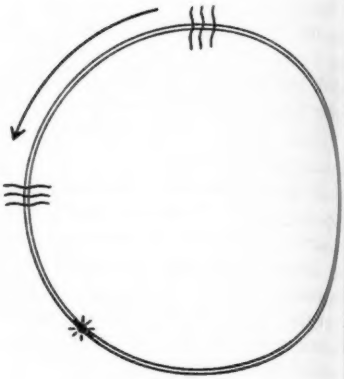


FIG. 3

previously recorded occurred during the wars of 1914–18 and 1939–45, when the phenomenon was explained as being due to the waves of alternate compression and expansion of air produced by heavy gunfire or explosions.

MEASUREMENTS OF WIND AND TEMPERATURE UP TO 100,000 FT. BY RADIO-SONDE AND RADAR

By F. J. SCRASE, M.A., Sc.D., F.Inst. P.

Summary.—The first observations of upper wind and air temperature up to 100,000 ft. to be made in this country by means of radio-sonde and radar have confirmed the occurrence, at these high levels, of easterly winds in summer and winds from a westerly quarter in winter. The lowest temperatures measured (in midsummer) occurred at about 50,000 ft., there being a rise from about −70°F. (−57°C.) at that height to −40°F. (−40°C.) at 100,000 ft. Some of the soundings indicated multiple tropopauses.

Introduction.—In the autumn of 1945 the Gassiot Committee of the Royal Society expressed the view that a need would shortly exist for sounding balloons capable of carrying radio-sondes to a height of 30 Km. (100,000 ft.). The development of such balloons has been pursued by the Instruments Development Division of the Meteorological Office in co-operation with the Research and Development Establishment, Ministry of Supply, and the Guide Bridge Rubber Company. A brief account of the earlier work on the problem was given by Ashford and Harrison[1*]. The average height to which a standard 500-gm. expanding rubber-latex sounding balloon will carry a radio-sonde weighing 1,500 gm. is about 60,000 ft. Ashford and Harrison reported the results of some trials with pairs of 700-gm. balloons in tandem, which reached heights averaging about 75,000 ft. A few ascents were also made with some experimental balloons weighing 4,500 gm. but these did not give any marked increase in height; moreover, the large size was a disadvantage both in construction and in launching. In the course of these trials it was found that, at the high levels reached, the windmill-operated switch of the radio-sonde ceased to function satisfactorily.

*These numbers refer to the list of references on p. 289.

Although great heights have been obtained in other countries by using non-extensible balloons made of plastic film, the size and fragile nature of such balloons limit their use to comparatively calm conditions. It was decided therefore to continue the development of rubber-latex balloons to reach heights of 100,000 ft. and of a size convenient for handling at normal radio-sonde stations.

An experimental batch of 2,000-gm. balloons was produced and after some of these had been used for inflation tests on the ground the remainder were used for flight trials. Seven out of nine ascents exceeded 95,000 ft. and the highest reached 102,300 ft. It is believed that the results obtained are the first balloon soundings of temperature and wind at these heights to be obtained by radio-sonde and radar in this country and it is the purpose of this note to put these results on record. A more detailed discussion of the balloon performance will be dealt with in a separate paper, but it may be of interest to mention here that the successful balloons expanded from an initial (unstretched) diameter of 6·5 ft. to just over 30 ft. at burst.

Ascents.—The first two ascents were made at Kew Observatory and were confined to the measurement of upper wind by radar observations of azimuth, elevation and slant range of a corner reflector attached to the balloon. The reflector was of the metallised nylon mesh type described by Ashford and Ferrer[2] and weighed about 800 gm. In the other ascents, which were made at the Meteorological Office aerological stations at Larkhill and Downham Market, the balloons carried both radio-sonde and radar reflectors. The radio-sondes, which normally transmit pressure, temperature and humidity readings, in turn, were adapted to indicate temperature only, thus avoiding the need for the windmill switch. To avoid possible temperature errors due to solar radiation falling on the temperature units the radio-sonde ascents were made at night. Extra lagging was provided for the standard radio-sonde batteries to guard against possible failure due to the longer time they would spend in the stratosphere.

Operational details for these soundings are included in Table I. The heights computed from the radar observations are corrected for the curvature of the earth. Occasions when winds were not strong were chosen for the ascents so as to avoid the balloons going beyond the radar range, about 66,000 yd. Observations were made every five minutes up to 30,000 ft. but above that height the radar observations were made every minute and the temperature readings every half minute. Wind speed and direction and temperature were computed for every 5,000 ft. from 30,000 ft. upwards and it is these data which are plotted in Fig. 1. The Downham Market ascent on July 1 is omitted from the diagram since the results were very little different from those on June 29. It will be noted that the two ascents on July 6 at Larkhill and Downham Market were practically simultaneous; the latter station is about 110 miles north-east of the former. The synoptic conditions for all the soundings were more or less anticyclonic.

Wind up to 100,000 ft.—The most noticeable features of the observations of wind are the large veer in direction, exceeding 100°, which occurred between 50,000 and 70,000 ft. and the comparative steadiness of direction above the latter height. A minimum in the wind speed also occurred between these heights. Table I summarises the quantitative information on these features.

TABLE I—SOME NOTICEABLE FEATURES ON HIGH BALLOON ASCENTS

	Date	Hour	Duration	Maximum height	Main change in wind direction*	Minimum speed*	Speed at 100,000 ft.	Minimum Temperature*	Tropopause Temperature*
	1949	G.M.T.	min.	ft.		kt.	kt.	°F.	°F.
Kew	Mar. 24	1400	82	102,000	130° (45) to 230° (65)	17 (50)	20	—	—
Kew	Apr. 19	1400	75	102,300	310° (50) to 90° (75)	6 (57)	12	—	—
Downham Market	June 29	2200	81	100,120	340° (50) to 85° (70)	8 (63)	26	−79 (42)	−79 (42)
Downham Market	July 1	2200	83	101,690	330° (55) to 80° (70)	10 (67)	28	−76 (41)	−76 (41)
Larkhill	July 2	2200	67	96,900	310° (50) to 80° (65)	6 (63)	24	−75 (53)	−70 (40)
Larkhill	July 6	2200	76	97,600	270° (55) to 90° (65)	7 (55)	23	−62 (56)	−60 (33)
Downham Market	July 6	2200	87	97,880	310° (50) to 90° (65)	0 (55)	24	−63 (60)	−62 (33)
	Means for last 5 ascents				310° (52) to 85° (67)	6 (61)	25	−73 (50)	−71 (40)

*Heights of these values are given in thousands of feet in brackets.

*Heights of these values are given in thousands of feet in brackets.

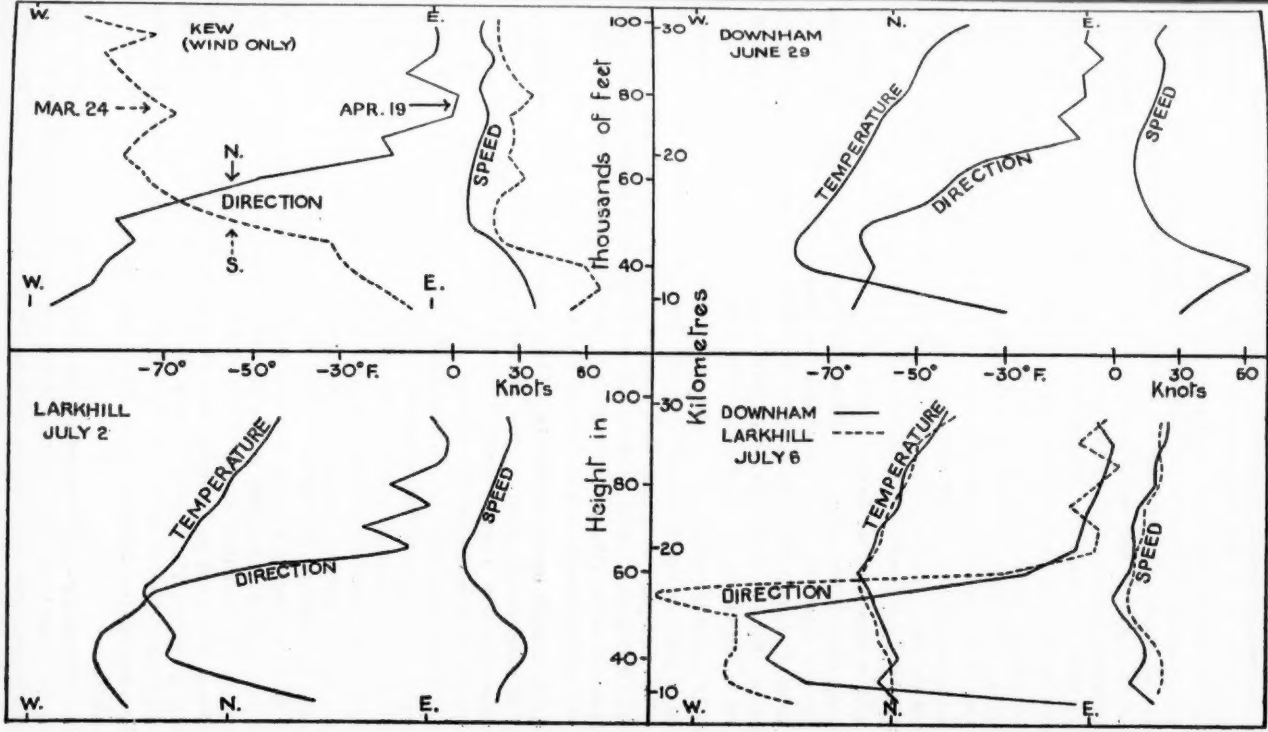


FIG. I—RADIO-SONDE AND RADAR OBSERVATIONS OF WIND AND TEMPERATURE UP TO 100,000 FT.

The soundings provide good confirmation of the "monsoon wind" theory of the late Dr. F. J. W. Whipple[3] who, from observations of the anomalous propagation of the sound of explosions and from a comparison of pressure and temperature differences between England and Lapland at a height of 20 Km. (65,000 ft.), deduced that the winds at such heights are from an easterly quarter in summer and westerly in winter. Johnson[4] reported some direct measurements of these winds by means of shell bursts at 30 Km.; these observations, which were made by Murgatroyd and Clews[5], showed that during the summer the wind at this height in south-east England is mainly easterly, with a mean speed of 23 kt., whereas in winter there is a strong westerly component averaging about 75 kt. Table I gives a mean wind at 30 Km. of 25 kt. from a direction of 85° for the five summer ascents. In these ascents the height above which the easterly winds prevailed was about 65,000 ft., which is nearly the same as the figure of 60,000 ft. quoted by Gutenberg[6] in a discussion of similar observations by high-altitude balloons in New Mexico and several other areas.

It will be noticed from Table I and Fig. 1 that, of the two soundings made in spring, that of March 24 showed a south-westerly wind in the upper levels, whereas the April 19 ascent indicated the summer type of wind structure. The time of change from one type to the other is consistent with Whipple's deduction that the transitions from W. wind to E. and *vice versa* occur at the end of March and in the middle of September.

All the soundings indicated a maximum of wind speed near the tropopause. In that of June 29 the maximum was very sharp, the decrease in speed above and below the peak at 40,000 ft. being about 25 kt. in 5,000 ft.; the wind direction in this case, as in all the other soundings except that on March 24, was approximately NW. The occurrence of such a sharp maximum wind speed near the tropopause suggests the existence of a "jet stream".

Temperatures up to 100,000 ft.—There have been so few direct measurements of temperature above 75,000 ft. in this country that the results of the soundings given in Table I and Fig. 1, though small in number and only representative of midsummer conditions, are of special interest. The chief feature, which they all show, is the steady rise in temperature with height in the lower stratosphere from a mean of -65°F. at 60,000 ft. to about -40°F. at 100,000 ft., *i.e.* a gradient of about $+0{\cdot}6$°F. per 1,000 ft. ($+1$°C. per Km.). Practically the same mean gradient, but with the temperatures about 6°F. higher, was obtained at the same time of year in the New Mexico soundings discussed by Gutenberg[6], who states that the agreement between the day and night data was good. On the other hand the day-time temperatures in the lower stratosphere at latitude 50°, calculated by Gowan[7] from the effect of the absorption of radiation in the ozonosphere under radiative equilibrium conditions, are about 30°F. higher than the observed temperatures at the same levels in England. The large difference can hardly be due to the fact that the soundings were done at night since Gowan[8] has also calculated that the cooling of the ozonosphere during a night should not amount to more than 4°F. at 100,000 ft.

The temperature-height curves for the ascents of June 29 and July 1 show well-defined single minima at about normal tropopause height. In the other soundings the curves have double minima, the lower one at the normal tropopause height of about 40,000 ft. and the other at about 55,000 ft. These features

can be interpreted as the overlapping of a multiple tropopause of the type first suggested by Bjerknes and Palmén[9] and more recently studied by Palmén[10]. It has long been known that the average height of the tropopause, when traced along a meridian from equator to pole, falls steeply between latitudes 20° and 40° in winter and 35° and 50° in summer. In the process of averaging, however, discontinuities tend to disappear, but it is known that the steep change in height of the tropopause is, in fact, a discontinuity between an upper, tropic, tropopause and a lower, arctic, one. According to Hess[11,12] the discontinuity, with some overlapping, occurs between latitudes 50° and 52° in North America in summer. It could, therefore, be expected to show up frequently in high soundings in England. Moreover, since the discontinuity is associated with the occurrence of the jet stream, some evidence of this, in the shape of the sharp maximum in wind speed near the low-level tropopause as was found in some of the soundings under discussion, could also be expected.

In the two simultaneous soundings of July 6 there was no significant difference between the temperatures at the same levels. The theoretical horizontal temperature gradient which would account for thermal winds with the speeds observed above 65,000 ft. in these ascents was computed to be 0·35°F. per 100 Km. This is about the distance north which Downham Market is from Larkhill. Such a small horizontal gradient could only be detected with the present radio-sonde over a considerably longer distance.

Future programme.—To investigate seasonal and latitude variations up to 100,000 ft. it is proposed to undertake a few high-altitude soundings each month, throughout a year, at two more widely separated stations. It is suggested that high-altitude balloons should be used, as far as possible, by Meteorological Services taking part in the special soundings on International Aerological Days.

Acknowledgements.—It will be evident that the results recorded in this note could not have been achieved but for the close co-operation of the Establishments and stations mentioned in the introduction; their assistance is gratefully acknowledged. The staffs of the radio-sonde stations at Larkhill and Downham Market, in particular, are to be commended for the care and zeal with which they undertook the specially long soundings, despite the fact that these were additional to their six-hourly routine soundings.

REFERENCES

1. ASHFORD, O. M. and HARRISON, D. N.; High-altitude sounding balloons. *Met. Mag., London,* **76**, 1947, p. 133.
2. ASHFORD, O. M. and FERRER, H. J.; The development of the Meteorological Office radar reflector Mk. IIB. *Met. Mag., London,* **77**, 1948, p. 224.
3. WHIPPLE, F. J. W.; The propagation of sound to great distances. *Quart. J. R. met. Soc., London,* **61**, 1935, p. 285.
4. JOHNSON, SIR NELSON; Wind measurements at 30 Km. *Nature, London,* **157**, 1946, p. 24.
5. MURGATROYD, R. J. and CLEWS, C. J. B.; Wind at 100,000 ft. over south-east England. *Geophys. Mem., London,* **10**, 1949, No. 83.
6. GUTENBERG, B.; New data on the lower stratosphere. *Bull. Amer. met. Soc., Lancaster, Pa.,* **30**, 1949, p. 62.
7. GOWAN, E. H.; Ozonosphere temperatures under radiation equilibrium. *Proc. roy. Soc., London,* A, **190**, 1947, p. 219.
8. GOWAN, E. H.; Night cooling of the ozonosphere. *Proc. roy. Soc., London,* A, **190**, 1947, p. 227.
9. BJERKNES, J. and PALMÉN, E.; Investigations of selected European cyclones by means of serial ascents. *Geofys. Publ., Oslo,* **12**, 1937, No. 2.

10. PALMÉN, E.; On the distribution of temperature and wind in the upper westerlies. *J. Met., Lancaster, Pa.*, **5**, 1948, p. 20.

11. HESS, S. L.; Some new mean meridional cross sections through the atmosphere. *J. Met., Lancaster, Pa.*, **5**, 1948, p. 293.

12. BANNON, J. K. and GOLDIE, A. H. R.; The stratosphere. *Met. Mag., London*, **78**, 1949, p. 98 (see Fig. 2, p. 102).

A NOTE ON CUMULONIMBUS PHOTOGRAPHED NEAR SINGAPORE ON MARCH 5, 1947

By J. M. CRADDOCK, M.A.

The eight photographs in Figs. 3–10 are selected from a series of 23 covering the same period, which was taken from the top of the water tower near Station Sick Quarters, Changi, Singapore Island, where the writer had spent most of the day observing cloud development. This point offers an excellent view of land and sea in all directions and a log, covering all matters of interest which were noticed, was kept during the whole period. On March 5, 1947, the visibility was very good, and during the afternoon it was evident that the cumulus cloud was occurring only over land. Until 1415 there had been no formation of cumulonimbus in any direction, but about that time the writer observed signs of the development to the south-east which forms the subject of this paper. The island of Bintan where it originated is mostly out of sight below the horizon, but the peak of Great Bintan (3,300 ft.) and the general cover of cumuliform cloud over the island are visible in the photographs. No other cumulonimbus development occurred during the day within the area of approximately 50 miles radius visible from Changi. Times in this article are given in zone time—$7\frac{1}{2}$ hours in advance of G.M.T.

The photographs show that, starting before 1417 a cumulonimbus rose to a great height over Bintan, and that the top was carried in an upper air stream directly towards Changi. The cloud top passed overhead at 1513. The cumuliform part had almost dispersed by 1505, but another cumulonimbus began to form at about 1530 in what appeared to be the same place, and reached its greatest vertical development at about 1554. Its later stages, not recorded photographically, were very similar to those of the first cloud.

A pilot balloon started from Changi at 1700 was followed to 29,000 ft., the following winds being typical of the sounding

Height (ft.)	5,000	10,000	15,000	20,000	29,000
Wind (°true/kt.)	270°/18	310°/19	050°/13	090°/15	080°/21

The upper air temperatures recorded at Tengah (about 15 miles from Changi) the same morning, starting at 0730, are shown on the tephigram in Fig. 1, and Fig. 2 is a sketch map of the area.

Calculation of sizes and velocities.—When an object is photographed, the size of the image depends on the size of the object, the distance of the object from the camera, the focal length of the lens used, and the direction of the optical axis of the lens in relation to the object.

If f is the focal length of the lens, θ the angle which a given diameter of the object subtends at the camera, and x the length of the image of the diameter, then, (1) if one end of the diameter lies on the optical axis of the lens, $\tan \theta = x/f$, and (2) if the mid point of the diameter lies on the optical axis of the lens, $\tan \theta/2 = x/2f$.

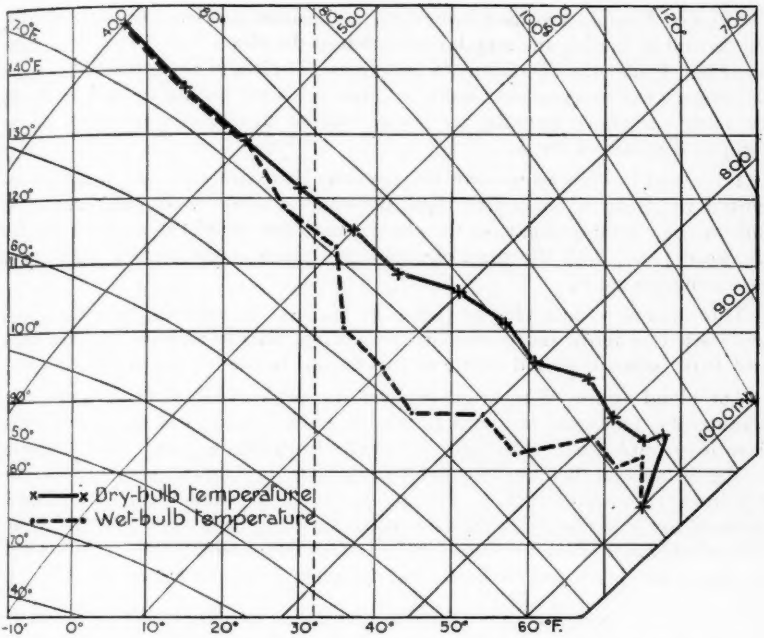


FIG. 1—UPPER AIR SOUNDING AT SINGAPORE (TENGAH) AT 0730 ON MARCH 5, 1947

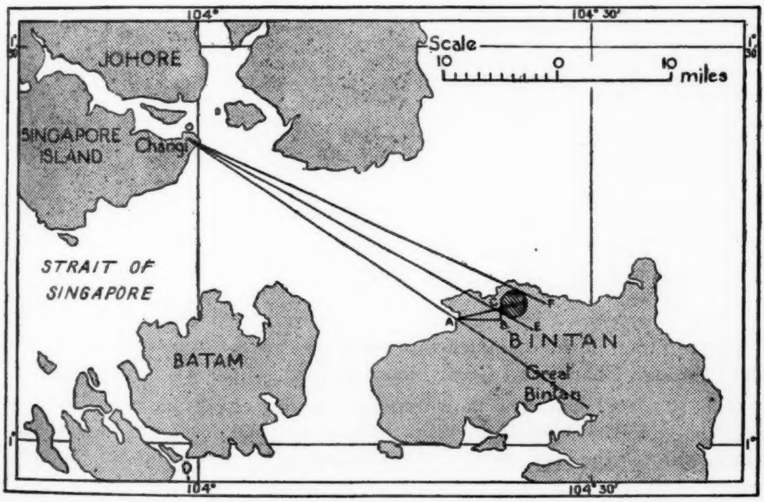


FIG. 2—MAP OF THE AREA SOUTH-EAST OF SINGAPORE

The first formula was used in finding the horizontal diameters of the clouds, the second in finding the angular elevation of the cloud tops above the visible horizon. Under the conditions of the observation it was not possible to ensure that the camera was pointed exactly towards the cloud, but the errors introduced by using the above formulæ are not considered to exceed 2 per cent. of the computed values of tan θ.

The cloud top moved towards Changi from the east-south-east, while the reported winds up to 29,000 ft. show no trace of a southerly component. It follows that the upper part of the cloud must have projected northwards over the lower, and, with the sun's elevation $7\frac{1}{2}°$ south of the local vertical, have cast a shadow on it.

This shadow is first clearly visible in Fig. 4. It appears, that the cloud top started to move north-west at about 1425, and its motion between then and 1513 (when it passed overhead at Changi) is taken to be uniform.

The cloud appeared to originate over the peak of Great Bintan, the only considerable mountain on the islands south of Singapore, and to rise vertically from then until 1425. The peak is 39 miles from Changi, and this is taken to be the distance of the cloud top until 1425. The horizontal speed of the cloud top from 1425 until 1513 is thus 49 m.p.h. The second cumulonimbus is assumed to rise vertically in the same place until 1547 and the top then to move towards Changi with the same speed. On these assumptions, the vertical heights of the clouds and the horizontal diameter of the first are given in Table I.

TABLE I—SIZE AND HEIGHT OF THE TWO CLOUDS

Time	Distance from Changi	Horizontal diameter	Height	Vertical velocity
	miles	× 1,000 ft.	× 1,000 ft.	ft./min.
First cloud				
1417	39	..	23·83	
1420	39	6·80	29·55	1,907
1425	39	8·03	38·80	1,850
1430	34·9	8·85	42·97	834
1435	30·8	10·98	41·70	
1438	28·4	12·16	42·30	
$1441\frac{1}{2}$	25·6	13·37	41·90	
1449	19·5	14·32	40·35	
1453	16·3	13·90		
Second cloud				
1524	39	..	19·8	
1530	39	..	21·0	200
1534	39	..	22·2	297
1538	39	..	23·5	320
1547	39	..	33·6	1,120
1554	33·3	..	43·2	1,375

The variation of the diameter with time, and a scale drawing of the vertical plane through Changi and Great Bintan are shown in Figs. 11 and 12.

Errors of observation.—The most important source of possible error lies in the estimate, 39 miles, of the distance at which the original development took place. The position of the apparent cloud top cannot be located within the horizontal section of the cloud, so that this measurement, which enters as a factor into all computed lengths and velocities, is subject to an error on this account of $1\frac{1}{2}$ per cent. Otherwise, the assumed distance is subject to independent

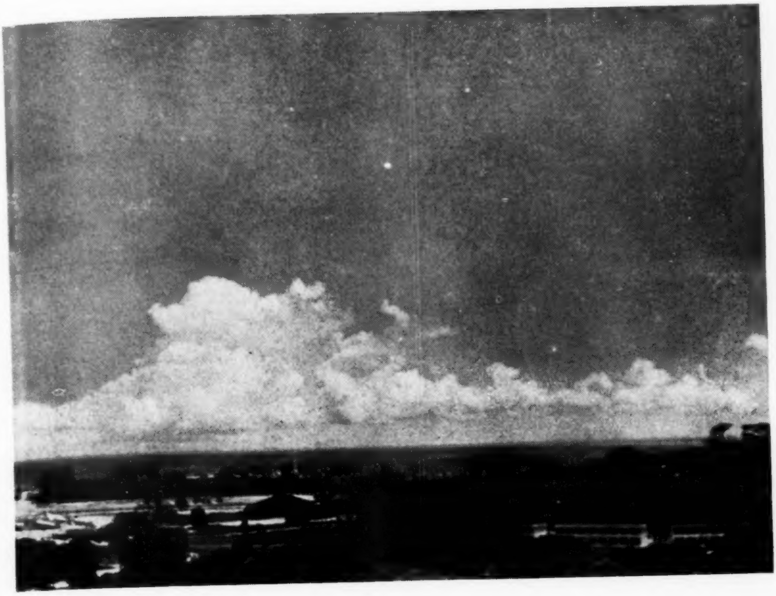


FIG. 3—CUMULONIMBUS AT 1417

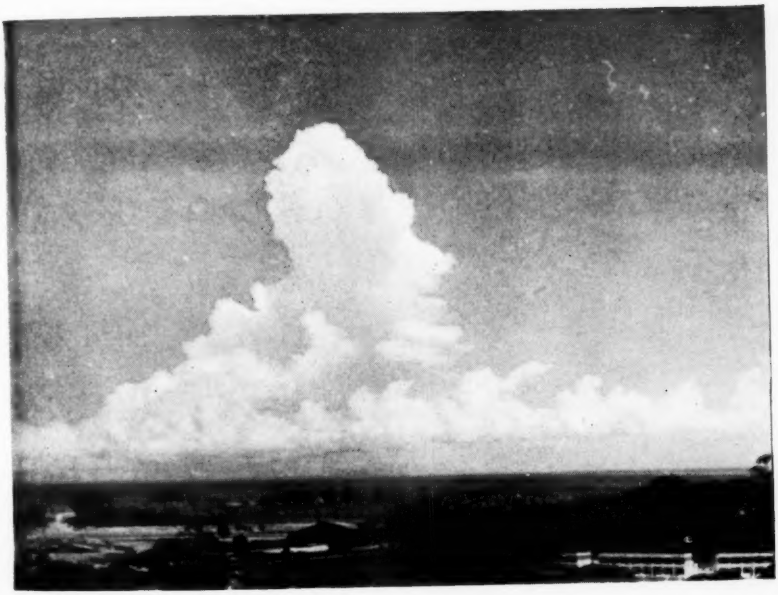


FIG. 4—CUMULONIMBUS AT 1430

CUMULONIMBUS PHOTOGRAPHED LOOKING SOUTH-EAST FROM CHANGI, SINGAPORE ISLAND MARCH 5, 1947

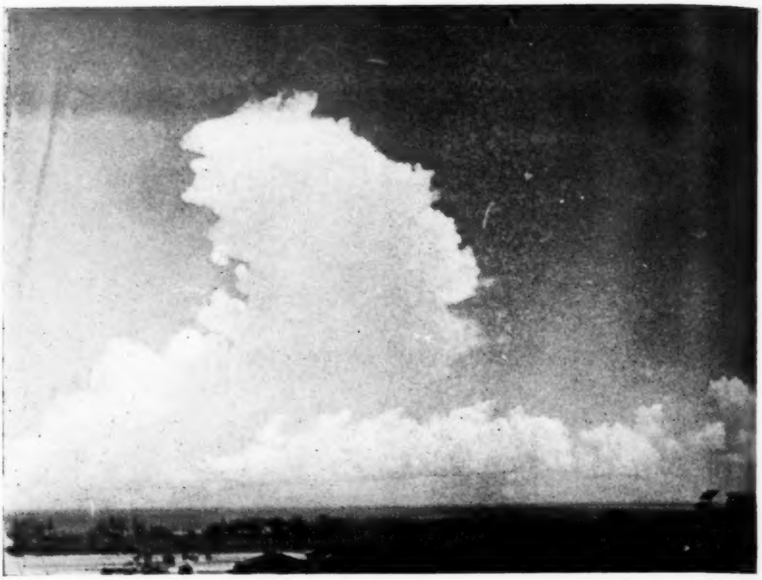


FIG. 5—CUMULONIMBUS AT 1438

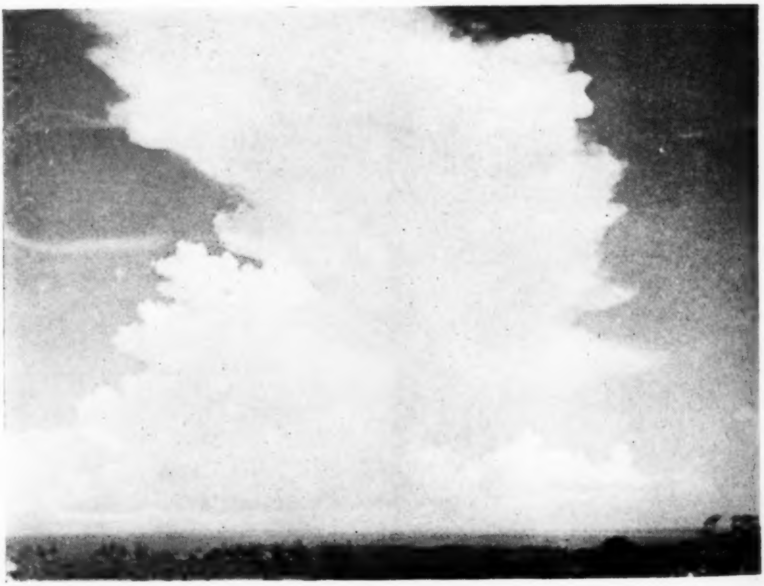


FIG. 6—CUMULONIMBUS AT 1453

CUMULONIMBUS PHOTOGRAPHED LOOKING SOUTH-EAST FROM CHANGI, SINGAPORE ISLAND, MARCH 5, 1947

FIG. 7—CUMULONIMBUS AT 1515

FIG. 8—CUMULONIMBUS AT 1527

CUMULONIMBUS PHOTOGRAPHED LOOKING SOUTH-EAST FROM CHANGI, SINGAPORE ISLAND, MARCH 5, 1947

FIG. 9—CUMULONIMBUS AT 1538

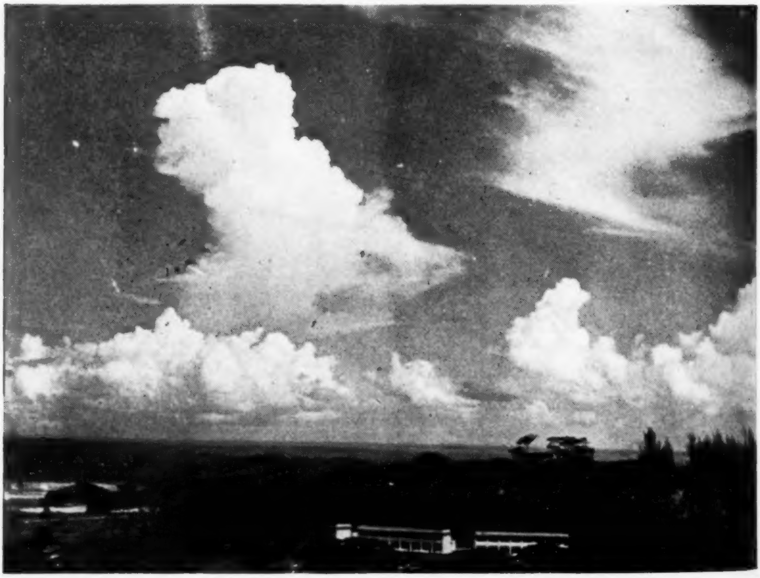


FIG. 10—CUMULONIMBUS AT 1554

CUMULONIMBUS PHOTOGRAPHED LOOKING SOUTH-EAST FROM CHANGI, SINGAPORE ISLAND, MARCH 5, 1947

confirmation. The peak of Great Bintan was obscured by a shower falling from the second cloud between 1538 and 1554, which precludes the possibility that the cloud rose behind the mountain. On the other hand, working on the calculated position of the cloud top at 1438, when the shadow was just crossing the edge of the small cumulus, it can be shown that the latter must lie over the area shaded on the map. The distance of the original development cannot be reduced by more than 10 per cent. consistently with the small cumulus being over land.

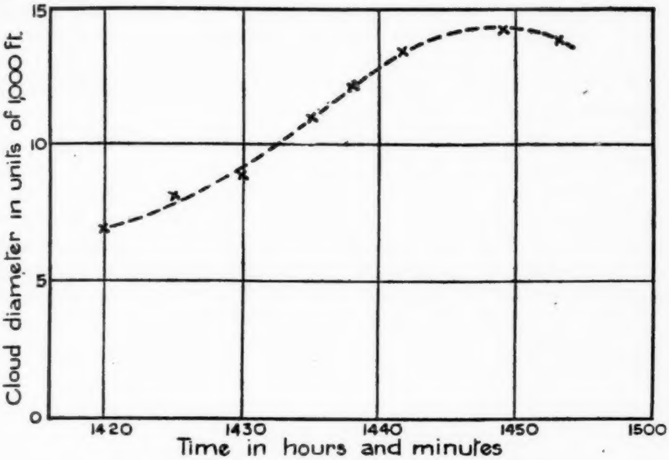


FIG. 11—CLOUD DIAMETER AT STATED TIMES

The heights are computed above the plane passing through the point of observation and tangential to the visible horizon in the direction of Bintan ; this differs from mean sea level by up to 200 ft. Also, the point of the cloud which appears highest in the photographs is not the true cloud top, but the error is considered to be small, of the order of 25–50 ft. The assumption of uniform horizontal motion cannot be checked, but the computed heights during the period of apparently horizontal motion (1430 to 1449) differ from their mean by less than 4 per cent., which suggests that the assumptions made are consistent to this degree of accuracy.

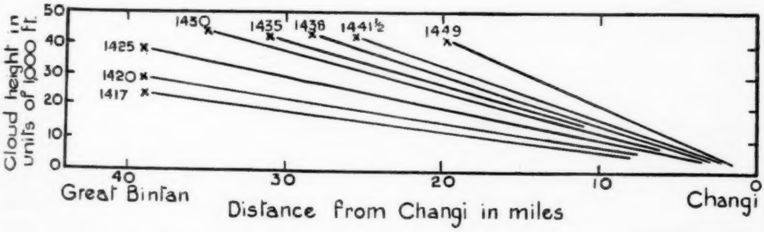


FIG. 12—DRAWING, APPROXIMATELY TO SCALE, SHOWING POSITION OF CLOUD TOP AT VARIOUS TIMES IN THE VERTICAL PLANE THROUGH GREAT BINTAN AND CHANGI

The estimates of vertical velocity, which relate to times when the clouds have little horizontal movement, are subject to a systematic error of the same order of magnitude and also to a random error of up to 6 per cent. due to an uncertainty of ± 5 sec. in the recorded times of the photographs. The estimates of cloud diameter are *prima facie* subject to the same error, though the smoothness of the curve plotted in Fig. 11 suggests that the actual error is smaller.

Mass and energy of the cumulonimbus.—The photographs show that a large bubble of saturated air broke away from its surroundings, and was dispersed at a much higher level. At 1420, when the bubble was first clearly separated, it appeared to include all the cloud above about 20,000 ft., or, say, a total weight of 150 gm./cm.^{2} cross-section. The cross-section, assumed circular, is about $4{\cdot}7 \times 10^{10}$ cm.^{2}, so that the mass of the cloud is about $7{\cdot}0 \times 10^{12}$ gm. and its water equivalent $1{\cdot}7 \times 10^{12}$ gm.

The excess heat energy carried by the bubble, compared with an equal mass of the environment, follows if ΔT, the mean difference in temperature between the cloud and the environment, is known. The reported upper air sounding, when plotted on a tephigram, makes it evident that ΔT is unlikely to exceed 7°F., while a lower limit may be found by means of the following equation, due to G. I. Taylor*, for the motion of a heated bubble rising by virtue of its buoyancy :

$$v^2 = (\text{const.})\ gd\ \Delta T/T,$$

where v is the terminal velocity of ascent, d a typical linear dimension, and T the absolute temperature of the environment. If the bubble has not reached its terminal velocity, and a is its acceleration, the equation may be written

$$a = g\ \Delta T/T - Kv^2/d$$

where K is the reciprocal of Taylor's constant and, on the analogy of a rigid sphere following O. G. Sutton, is taken to be greater than or equal to unity.

Now, assuming that the bubble moved with constant acceleration from 1417 to 1425, its velocity at 1420 was $953{\cdot}8$ cm./sec. and acceleration $-0{\cdot}125$ cm./sec.^{2}. The appropriate value of T is about 259°A., so that the equation reduces to

$$\Delta T = 2{\cdot}03K - 0{\cdot}06$$

Thus the following values of ΔT in degrees Fahrenheit correspond to different possible values of K.

K	..	1	2	3	4
ΔT	..	2·03	4·13	6·22	8·32

Hence ΔT cannot be less than 2°F., while, since it cannot exceed about 7°F., it follows that K does not exceed 3.4.

The possible range for ΔT is thus from 2°F. to 7°F. The heat energy represented by the latent heat of condensation of the water vapour in the bubble has now to be considered. Since the cloud is saturated while the environment is not, this cannot be less than the amount by which the latent heat of condensation of air saturated at the temperature of the bubble exceeds that of air saturated at the temperature of the environment. It may, of course, be much greater. If we write $\Delta T'$ as the difference in equivalent temperatures,

*SUTTON, O. G. ; The atom bomb trial as an experiment in convection. *Weather, London*, 2, 1947, p. 105.

then this must exceed 3·8°F. It follows that the excess heat energy of the bubble, compared with an equal mass of the environment, exceeds $3{\cdot}5 \times 10^{12}$ calories.

It is of interest to compare this with the figure quoted by Sutton for the energy released in the Bikini atom-bomb explosion, namely 2×10^{13} calories.

It must be emphasised that the clouds here discussed, though observed under exceptionally favourable photographic conditions, are in no way exceptional from the meteorological aspect. On the contrary, they are perfectly ordinary features of Malayan weather. The present photographic record is capable of being duplicated by any observer having a good camera.

DETERMINATION OF THE TRUE MEAN VAPOUR PRESSURE OF THE ATMOSPHERE FROM TEMPERATURE AND HYGROMETRIC DATA

By E. J. SUMNER, B.A., and G. A. TUNNELL., B.Sc.

Part II

Calculation of mean vapour pressure from the means of wet- and dry-bulb temperatures.—The partial pressure exerted by the water vapour in the atmosphere is most conveniently measured by wet- and dry-bulb thermometers enclosed in a ventilated screen. Theoretical expressions have been derived by a number of writers for the vapour pressure in terms of these two temperatures, the simplest and most generally used being due to August* (1825). The equation is of the form

$$e = a\,(T_1) - A[T - T_1] \qquad \cdots \quad (9)$$

T_1 being the wet-bulb temperature and A a constant at a given temperature and pressure. It is the one on which the British hygrometric tables† are based; a constant pressure of 1000 mb. is assumed and A for observations in screens is empirically determined as 0·444 for T_1 above 32°F. and 0·400 for wet-bulb temperatures below freezing. There are several refinements to this formula, the commonest being

$$e = a\,(T_1) - B[T - T_1]\left\{1 + \frac{T_1 - 32}{\gamma}\right\},$$

B and γ being constants ; but the additional term is very small and in the original paper it has been shown that it plays a negligibly small part in the determination of the error of the means. We shall therefore discuss equation (9) only. It should be noted that the wind velocity is not included in the equation although it is known experimentally that the wet-bulb depression is very sensitive to wind-velocity changes up to about 5 m.p.h., and insensitive above. Some account may be taken of this effect usually by giving different values to A for varying exposures, and ideally the screen should be aspirated to maintain standard flow conditions past the wet bulb. However, we are not concerned here with the inaccuracies of the formula, but with what happens in the process of averaging assuming that it gives correct results.

*AUGUST, E. F. ; Über die Verdungstungskalte und deren Anwendung auf Hygrometrie. *Ann. Phys., Leipzig*, **5**, 1825.

†London, Meteorological Office. Hygrometric Tables, London, 4th edition, 1940 (Reprinted 1949).

If there are n observations of T and T_1, each of which determines a value of e in equation (9), then summing and dividing by n we get

$$\bar{e} = \frac{1}{n}\Sigma e = \bar{a}(T_1) - A[\bar{T} - \bar{T}_1].$$

If E_1 is the value of the vapour pressure computed from the mean wet- and dry-bulb temperatures, then

$$E_1 = a\,(\bar{T}_1) - A\,[\bar{T} - \bar{T}_1]$$

and therefore the correction, S, to be added to this value to give the true mean is given by

$$\begin{aligned} S &= \bar{e} - E_1 = \bar{a}(T_1) - a(\bar{T}_1) \\ &= \frac{a\,(\bar{T}_1)\sigma_{T_1}^2}{2\,\bar{T}_1^4}[\alpha^2 - 2\alpha\,\bar{T}_1] \end{aligned} \qquad \cdot\cdot \quad (10)$$

from equation (4). This expression is always positive so that the true mean vapour pressure is always higher than the computed value. The error increases steadily as the mean wet-bulb temperature rises* and is proportional to the variance of the wet-bulb data. The following conclusions based on worked examples and general experience have been drawn :—

(*a*) For fixed hours the correction to be added to the vapour pressure computed from monthly mean wet- and dry-bulb temperatures is generally of the order of 0·0–0·2 mb., while 0·5 mb. seems to be the extreme value. Although the error increases rapidly with wet-bulb temperature, since high wet-bulb temperatures are usually associated with small ranges of wet-bulb and *vice versa*, the greatest corrections are found in temperate regions where the greater ranges of the wet-bulb data often more than compensate for the lower temperature.

(*b*) For daily or monthly means the correction is of the same order as hourly means, and compares very favourably with those which arise when temperature and relative humidity means are used. It will be remembered that the biggest errors in the latter case occurred when the diurnal vapour-pressure profile showed a marked minimum at the time of maximum temperature, *i.e.* with big relative-humidity ranges, when the wet-bulb temperature would tend to remain steady and, in any case, the error is inherently smaller than previously.

(*c*) The annual variation of wet-bulb temperature may be almost as big as that of the dry bulb, and the required corrections are often very large for annual means. In temperate regions they may well exceed 2 mb., and sometimes double this value in polar-continental regions. To avoid such large errors it is better to compute the twelve monthly values of vapour pressure from the mean monthly wet- and dry-bulb temperatures and average them.

Other hygrometric elements.—Dew-point temperature and saturation deficit are the only other elements of sufficiently wide use to merit attention. If t is the dew-point temperature, then the vapour-pressure (e) is, by definition, equal to $a(t)$ the saturation vapour pressure at the dew-point. Therefore

$$\bar{e} = \bar{a}(t) = a\,(\bar{t})\left\{1 + \frac{\sigma_t^2}{2\bar{t}^4}\,[\alpha^2 - 2\alpha\bar{t}]\right\} \qquad \cdot\cdot \quad (11)$$

*It can easily be shewn that the function $a(\theta).\,[\alpha^2 - 2\alpha\theta]/2\theta^4$ always increases with θ.

from equation (4). Thus the problem of finding the true mean vapour pressure is reduced to that of finding the standard deviation of the distribution of dew-point temperatures.

Saturation deficit, defined as the difference between the saturation vapour pressure and the actual vapour pressure of the atmosphere, is a term most frequently used in agricultural climatology. It is just as good an indicator of the " dryness " of the air as relative humidity, but what particularly commends its use, from our point of view, is the fact that the true mean vapour pressure can be calculated from the mean temperature and the mean deficit without knowing the standard deviation of the latter. For if q is the saturation deficit, then $q = a(T) - e$ and taking means of both sides.

$$\bar{q} = \bar{a}(T) - \bar{e} \qquad \text{.. (12)}$$

The above statement follows immediately from this equation ; $\overline{a}(T)$ can be calculated in the usual way from the temperature data.

The rest of this article will be devoted to ways and means of computing the required corrections in certain cases.

Calculation of the errors.—All the equations we have deduced contain averages of the climatic elements concerned and also their standard deviations. Unless we can calculate these standard deviations from the published information the true mean vapour pressure is not accurately determinable, or if, as is sometimes the case, we have at our disposal all the hourly values the labour of converting each pair of values to the vapour pressure and averaging may be prohibitive, and calculating the standard deviations by the rules given below may be quicker and sufficiently accurate to warrant their application.

The function* $\Theta_T = \dfrac{a(\overline{T})\sigma_T^2}{2\overline{T}^4}[\alpha^2 - 2\alpha\overline{T}]$

occurs in all our equations and $\alpha a(\overline{T})\sigma_T / \overline{T}^2$ (*i.e.* σ_a) in one of them. To facilitate rapid calculation they have both been plotted graphically (see Fig. 1), so that given σ_T and $\overline{T}$, their values can be read off directly. For a particular mean temperature σ_a is proportional to σ_T, so that for values intermediate to those represented by dotted lines on the graph we may interpolate linearly in a vertical direction. This cannot be done with the function Θ_T, but the lines are drawn sufficiently close together for one to get an accurate value without much trouble. The problem is how to find the σ's, and the methods employed depend on the type of frequency distribution.

Consider first of all monthly tables of dry-bulb temperature and relative-humidity data. Here equation (7) is the one to use. If monthly mean values at each hour are available, to obtain the required standard deviations divide the mean daily ranges by $\sqrt{8}$. This is tantamount to assuming that temperature and humidity follow a simple sine curve in their diurnal cycle, and this procedure has been found to give remarkably accurate results, usually within 5 per cent. For convenience, a scale has been set up on the right of Fig. 1, so that, given the mean diurnal range of temperature one can read off the values of σ_a and Θ_T for use in (7) without doing the preliminary calculation of σ_T. This scale can also be used to find σ_b from the mean diurnal range of relative humidity by reading across from one scale to the other. Whenever it is obvious on

*T here and in Fig. 1 refers to the dry-bulb, wet-bulb or dew-point temperature as appropriate.

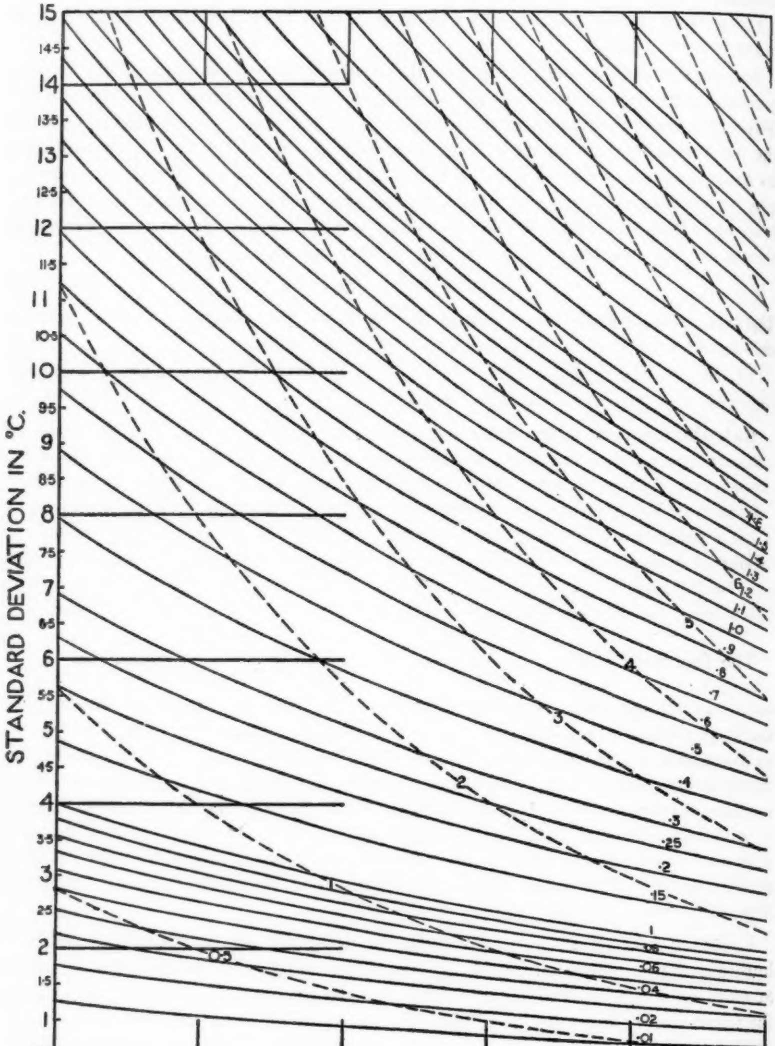
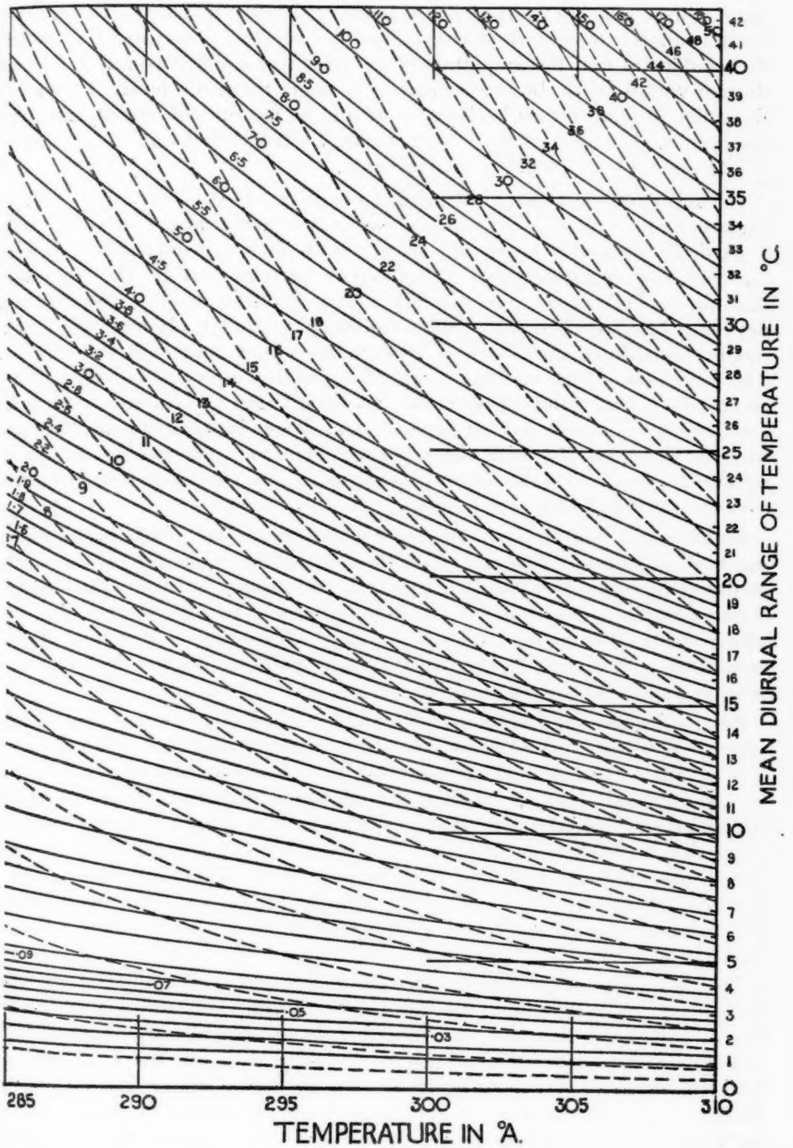


FIG. I—DIAGRAM FOR ESTIMATING ERROR IN MEAN VAPOUR PRESSURE (mb.)

The correction to be added to the saturation vapour pressure at the mean temperature in ord
The standard deviation of the saturation vapour pressure is given by the set of dotted lines.



WHEN CALCULATED FROM AVERAGES OF OTHER HYGROMETRIC ELEMENTS

determine the mean saturation vapour pressure is represented by the set of thick continuous lines.

inspection or reasonable to assume that the data (whatever it is) is distributed more or less cyclically this device may be used. If the range of relative humidity is not available, most stations give at least two or three observations a day and these suffice to find the amplitude of the relative humidity assuming that the diurnal variation can be represented by a single harmonic term. Frequently the range of temperature is given by M and m, the monthly mean maximum and minimum temperatures. In this case, σ_T has been found to be equal to $\{\frac{1}{3}(M-m)-\frac{1}{2}\}$°C. within 5—10 per cent.

In many cases the data is distributed in a haphazard sort of way. For example, suppose we have all the daily values of wet-bulb temperatures at a given hour for a particular month over several years. It is obviously impractical to work out each corresponding value of the vapour pressure and get the true mean that way. Fortunately one can get a very good estimate of the standard deviation of a random set of data consisting of 28–31 observations (*i.e.* a month) by dividing the difference between the greatest and least values by 4·3. The correlation of the monthly range of wet-bulb temperature divided by 4·3 against its actual standard deviation has been found to be 0·94, and similar accuracy is to be expected for dry-bulb and dew-point temperatures. In this way, we may quickly work out the corrections for each month in turn by equation (10) using Fig. 1, and average the true mean vapour pressures obtained over the period of years in question.

Finally, equation (10) cannot be used when the wet-bulb data includes readings both above and below 32°F. since the constant A is subject to a discontinuity at this temperature, and for averaging the data must be separated into two classes. Similarly equation (7) should only be used for relative-humidity data with respect to water or supercooled water. The practice of giving relative humidities with respect to ice below freezing point makes the data unhomogeneous and difficult to deal with.

Resumé and conclusion.—The thermal and hygrometric state of the atmosphere may be specified by many different parameters, and for a single occasion it is of little importance which combination of variables is adopted since one set can be readily converted into another by virtue of the relations which exist between them. However, as we have seen, when mean values are involved this conversion becomes more difficult. It is therefore advisable to deal only with those elements which are of most direct use and which are relatively independent. Dry-bulb temperature is, of course, the universally accepted element specifying the thermal state of the air, but no such agreement exists with respect to moisture content.

The two entities dry-bulb temperature and vapour pressure are related by the general energy balance of the atmosphere, but the relationship is so complex and so ephemeral that we may conveniently consider them as independent variables. On the other hand relative humidity is a non-linear function of both temperature and vapour pressure, and, by itself, gives no indication of the absolute amount of moisture in the atmosphere. Moreover, it does not enter explicitly into hygrometric and thermodynamical equations whereas vapour pressure does, which is an equally cogent reason for using the latter. Wet-bulb temperature, saturation deficit, and dew-point temperature are also subject to similar criticisms, and it is evident that dry-bulb temperature and vapour pressure have greater claim to figure in climatic tables. If the other

elements must be used their standard deviations or at least their range should be published as well. If a climatic table does not contain this information (and, except possibly for temperature, this is all too often the case) then no amount of ingenuity will enable one to calculate the true mean vapour pressure correctly, and it is obvious that such a table is incomplete.

The equations we have derived, although of interest in themselves, perhaps anticipate the day when standard deviations as well as arithmetic means are part of the stock-in-trade of the professional climatologist, and when meteorology is a much more exact science than it is today.

In drawing mean-vapour-pressure maps many other sources of error have to be taken into account, instrumental and errors of reduction to a standard height being the largest, and it may be considered academic to attempt to compute errors of 0·5 mb., say, when the hygrometer in use is possibly not accurate to this degree. However, the authors are of the opinion that if several errors enter into the determination of a particular value it is always something gained to eliminate or reduce one of them.

OFFICIAL PUBLICATION

The following publication has recently been issued:—

Annual Report of the Director of the Meteorological Office presented by the Meteorological Committee to the Secretary of State for Air for the year April 1, 1948 to March 31, 1949.

This report contains an account of the work of the Meteorological Office which, as the State meteorological service, is responsible for meeting the needs of the public, the Royal Air Force, the Merchant Navy, Civil Aviation and Government Departments generally.

Among important developments during the past year may be mentioned the work of the Forecasting Research Division at Dunstable. This Research Division works at the headquarters of the forecasting service, and has at its disposal meteorological information covering the entire northern hemisphere, collected with the maximum possible speed under an internationally operated scheme. Highly complex dynamical investigations are in progress with the object of strengthening the scientific foundation of forecasting technique. Special studies are also made of occasions when weather developments have not been in accordance with anticipations.

The international scheme for maintaining weather ships in the North Atlantic Ocean made further progress, the number of such stations in operation in March 1949 increasing to 11. These include the two stations maintained by the United Kingdom some 500 miles westward of the British Isles, and a third station maintained jointly by Norway, Sweden and the United Kingdom midway between Norway and Iceland.

The air-lift operations to Berlin necessitated considerable expansion of the meteorological services provided for the Royal Air Force in Germany. Development has also taken place in connexion with civil aviation, the most important feature being the establishment of the new Air Traffic Control Centre at Preston, Lancashire. The demands for meteorological advice at London Airport show a continued increase, not only in respect of the number of aircraft operating, but also in regard to the nature of the information required. In this connexion, special attention is being paid to the accurate measurement of visibility at night, as affecting the safety of aircraft landing in unfavourable weather.

Research has been pursued in problems of atmospheric physics which have practical application to the safety of aircraft. Increasing attention is being given to the meteorological needs of agriculture. Much effort was also devoted to the development of meteorological instruments. Records of terrestrial magnetism, seismic movements, and atmospheric electricity have been maintained at the Observatories.

Representatives of the Meteorological Office took part in a number of international conferences which were held in London, Paris, De Bilt, Geneva, Oslo, Delhi, Seattle and Buenos Aires.

The Meteorological Reserve was re-formed as part of the reconstituted Royal Air Force Volunteer Reserve.

ROYAL METEOROLOGICAL SOCIETY

The annual summer outing of Fellows of the Royal Meteorological Society and their friends took the form this year of a visit on July 13 to the Royal Aircraft Establishment at Farnborough, Hampshire.

The party were welcomed by the Director, Mr. W. G. Perry, who described the general functions of the Establishment as concerned with research and development into all aspects of aeronautics, from the strength of the materials used in making aeroplanes to the gustiness of the upper atmosphere.

The programme before lunch consisted of a demonstration, with a sandbag, of the ejector seat used for escape from very fast aircraft, and of the methods used in the Strength of Materials and Aircraft Structures Laboratories. In the Structures Laboratory complete aircraft wings and other parts are tested to destruction to see whether and by how much they can withstand the greatest load likely to be imposed in flight, taking into account atmospheric turbulence and other factors.

After an excellent lunch in the R.A.E. canteen the party were in good form for the high-light of the day, the description of the work of the Meteorological Research Flight by Dr. Frith and his colleagues.

Much of this work was recently described by Dr. Frith himself in the *Meteorological Magazine**, so reference in any detail is needed in this account to newer work only. Mr. Goody explained the work being carried out by the Meteorological Office and Cambridge University on the variation of the intensity of solar radiation with wave-length at high altitudes using a high-speed thermistor bolometer. The instrument scans the energy distribution over a range of $1\ \mu$ in 7 sec. The range of $1\ \mu$ may be preselected to be anywhere within a wide band. Diagrams of the variation measured at 30,000 ft. in the region of the water-vapour absorption band at $6{\cdot}3\ \mu$ were shown from which the mass of water vapour in higher layers of the atmosphere can be calculated. A demonstration with an artificial " sun " of an electronic heliostat devised to keep the sun's rays on the slit of the spectroscope used in this work aroused much interest. The heliostat not only keeps the sun shining on the slit but " finds " the sun beforehand. Mr. Shellard showed the technique due to Dessens of capturing dust particles and condensation nuclei on fine fibres. By projection on a small screen, nuclei were shown growing to spherical droplets as relative humidity was increased to room level and decreasing to small crystals as the air stream across the particles was dried.

*FRITH, R. ; Meteorological Research Flight. *Met. Mag., London,* **77**, 1949, p. 241.

Dr. Frith explained the well-known Dobson-Brewer frost-point hygrometer and three instruments intended to measure water content and drop size in clouds. Two of these are based upon the principle that the amount of water caught by a cylindrical rod projecting from the aircraft depends on the diameter of the rod and the size of the droplets because a thin rod disturbs the air stream relatively little and catches most drops in its path, and a thick one disturbs the flow so much that the smaller drops are carried round and only the larger ones go on to hit the cylinder. In one application heat is supplied to such a rod at a known rate and the amount of water caught by it can be calculated from the temperature of the rod and some other factors. By using four such cylinders a measure of the distribution of drop size is obtained. In the other application used in ice-forming clouds the cylinders are steadily rotated and the amount of ice caught on each is measured. The third instrument used the magnesium oxide slide as described in Dr. Frith's article. Mr. Grant demonstrated a very responsive thermometer being developed for use in aircraft which under low ventilation has a lag coefficient of only a fiftieth of a second and an even smaller one in aircraft use.

From the Meteorological Research Flight the party were conducted over the station Meteorological Office, the Flying Control Office with its elaborate radar apparatus, and were shown a number of modern aircraft. Tea in the canteen concluded the day's proceedings.

NOTES AND NEWS

International Meteorological Organization postage cancellation design

We are indebted to Dr. G. Swoboda, Chief of the Secretariat of the I.M.O., for permission to reproduce in the Magazine the design now used, with the standard Swiss post office place and date stamp, in the postage cancellation machine at the I.M.O. Secretariat. The device thus appears on all envelopes coming from the I.M.O.

Readers will recognise immediately the symbols and the familiar shapes on the outer curve of the design.

The Bishop Shield

In this age of excessive specialization it has become increasingly difficult to achieve success in two fields at the same time. It is accordingly a matter for special gratification when the Meteorological Office carries off the Bishop Shield against the competition of the rest of the Air Ministry and the Ministry of Civil Aviation, as it did at the Sports Meeting on August 31, 1949. To win the shield it is necessary to excel in games like football and cricket as well as in athletics and swimming, and it is this overall quality which endows the holding of the shield with such value.

While chief credit must, of course, go to the individual performers of both sexes, a measure of the success of the Office as a whole must be attributed to the enthusiasm of the energetic members of our Sports Committee. In view of the fine team spirit that has been shown, it might be considered invidious to refer to individuals, but it would be less than fair to omit mentioning the achievements of Mr. A. F. Lewis as a swimmer and of Mr. W. Lawson as a medium-distance runner. A special word of praise is due to the ladies, amongst whose efforts the graceful high jumping of Miss Pope and Miss Gilpin earned the applause of the spectators at the Polytechnic Stadium. We must also not forget the indefatigable Secretary of our Committee, Mr. H. A. Scotney, the work done by Mr. P. M. Shaw in rallying the staff at Harrow, and the similar task performed by Mr. R. M. Rudlin at Dunstable.

To all who have contributed in any way towards the winning of the Bishop Shield I offer the warmest congratulations of their colleagues in the Meteorological Office. Is it too much to hope that next year we may place beside it the Simpson Cup, and thus honour the former Director whose name it commemorates ?

N. K. JOHNSON

NEWS IN BRIEF

The Council of the Physical Society has awarded the Charles Chree Medal and Prize for 1949 to Dr. G. M. B. Dobson, F.R.S., for his work on physical meteorology, especially on the physics of the upper air.

REVIEW

Atmospheric Electricity. By J. Alan Chalmers. 8vo. 9 in. $\times 5\frac{1}{2}$ in. viii + 176. Geoffrey Cumberlege, Oxford, Clarendon Press, 1949. Price: 15*s*. 0*d*.

Atmospheric electricity is usually regarded as forming a well defined section of geophysics but its connexion with meteorology is naturally very close. In such aspects as the conduction of electricity in the air it can be treated under the heading of pure physics, whilst there are certain applications of atmospheric electricity, such as lightning protection, which are more appropriate to the realm of applied physics. One finds, therefore, that published work on the subject is scattered through a wide variety of scientific journals, and, as in many other subjects, it is no easy task to keep track of research that is going on in various parts of the world. For some years now there has been a need for one of the active workers on atmospheric electricity to collect together the main results, particularly of recent work, in book form. Dr. Chalmers, who is well known for his own researches on the subject, has undertaken this task and the book he has written is one which, despite one or two limitations, can be recommended to every student or worker on the subject.

One of the limitations is that the author does not treat his subject in a very discursive manner, and although there are advantages in having the essentials of the subject presented in concise form one cannot escape the feeling that the book is a well arranged collection of very good abstracts. The descriptive background and the critical analysis of theories and results are kept down to a bare minimum. While, therefore, the book forms a very handy and comprehensive source of reference for the student or research worker the newcomer may find it rather a dry introduction.

Another limitation is that although, according to the notice on the dust cover, the book purports to include results of the latest work which has only been available previously in scientific journals, it does not mention the work of Findeisen in Germany in 1943 and of Frenkel in the U.S.S.R. in 1944. Both these workers have put forward theories to account for the generation of electric charge in clouds, and although these theories may not be generally accepted, one would expect to find them referred to in an up-to-date account of the subject. On the other hand it is noteworthy that the very recent work of Simpson on the electricity of disturbed weather has been included.

These two criticisms, however, are minor ones, and the writer would like to emphasise his view that the book is a very welcome addition to the literature of the subject. No text-book on atmospheric electricity, in the English language, more recent than the volume published in 1939 in the " Physics of the Earth " series, was available until Dr. Chalmers' book appeared, and despite the war years and the fact that the subject has relatively few military applications, a surprising amount of work seems to have been done in the interval.

The lay-out of the book is well balanced. After a historical introduction and a summary of general principles the various aspects of the subject are dealt with in detail. These include atmospheric ionization, the earth's electric field, currents due to conduction, precipitation and point discharge, and thunderstorm electricity. Cosmic rays and earth currents, which have come to be regarded as being outside the scope of atmospheric electricity, are excluded. The book is provided with a good bibliography and author and subject indexes.

There is scarcely any need to say that the production of the book is well up to the high standard one expects from the Clarendon Press. The volume forms one of their international series of monographs on physics and the price compares very favourably with those of the other volumes in this series.

F. J. SCRASE

WEATHER OF AUGUST 1949

Mean pressure for August was 1020 mb. or above over an area extending from west of the Azores north-eastwards across the Atlantic, the Bay of Biscay, northern France and the English Channel. It decreased northwards to 1010 mb. or below in northern Norway, the Faeroes, Iceland and over the western Atlantic north of about 55°N. Mean pressure was above the average over most of the north-eastern Atlantic and western and central Europe including Scandinavia; the greatest excess, 5 mb. above the average, was over the British Isles. Pressure was generally below the average near the Azores and over the western Atlantic.

Broadly speaking, the weather over the British Isles was dry in England and Wales, Northern Ireland and south Scotland, but wet in the west and north of Scotland, particularly the north-east. It was sunny in England and Wales and south Scotland; mean temperature exceeded the average generally.

Unsettled weather prevailed for the most part during the first ten days. From the 1st to the 3rd a complex depression moved across the northern half of the British Isles to southern Scandinavia. Rain fell generally on the 1st and showers and local thunderstorms on the 2nd; rainfall was heavy in central Wales on the 1st, 2·02 in. being measured at Hafod Fawr, Merioneth. In the

rear of the depression on the 3rd, strong north-westerly winds prevailed, reaching gale force locally, and scattered showers were recorded mainly in the northern half of the country. Another deep depression, which was situated over the Atlantic westward of Scotland on the 5th, moved north-east to Thorshavn by the 8th. Meanwhile associated troughs of low pressure crossed the British Isles giving rain in the north and west. On the 7th and 8th a vigorous depression north-east of the Azores moved quickly across England to Scandinavia causing local gales on the 7th and 8th and heavy rain in some areas on the 7th. At many places in Scotland and Northern Ireland rainfall on the 7th amounted to more than 2 in.; *e.g.* 2·90 in. at Loch Vennachar, Perthshire, 2·43 in. at Kilmarnock, Ayrshire, and 2·07 in. at Annalong, Mourne Mountains. On the 9th an anticyclone situated south-westward of the British Isles moved slowly east and on the 10th a shallow secondary depression off north-west Ireland moved south-east to the southern North Sea and thence east to Germany where it filled. Rain occurred generally on the 10th. On the 11th a small anticyclone westward of Scotland moved south-east and fair weather prevailed apart from slight rain in the Hebrides and extreme north-west of Scotland. Subsequently, pressure was high in a belt extending from south-west of Ireland across southern England to Germany; meanwhile, troughs or shallow secondary depressions moved east over the northern half of the country. Fair, warm weather prevailed in England and Wales, but rain occurred at times in Scotland and Northern Ireland; temperature rose to 88°F. at Greenwich on the 15th. On the 17th an anticyclone situated west of Ireland moved south, and from the 17th to the 19th a trough of low pressure moved slowly east giving rain at times, chiefly in the western half of the country. On the 20th and 21st an anticyclone over the British Isles moved away east-south-east to Germany; very warm weather prevailed and it was fair in England and Wales, but rain occurred in north Scotland on the 20th and local thunderstorms in Scotland and Ireland on the 21st. From the 23rd to the 27th pressure was fairly uniform over the British Isles, and, apart from scattered rain or thunderstorms, mainly fair weather prevailed, though there was considerable mist or fog. From the 28th to the 30th a complex Atlantic depression moved north-east across Iceland while a trough crossed the British Isles. Rain fell in the west on the night of the 28th–29th and more generally, apart from south-east England, on the 29th, while scattered rain and local thunderstorms were experienced on the 30th. On the last day of the month a trough of low pressure to the west of Ireland moved east, giving rain generally and rather widespread thunderstorms.

The general character of the weather is shown by the following provisional figures:—

	Air Temperature			Rainfall		Sunshine	
	Highest	Lowest	Difference from average daily mean	Percentage of average	No. of days difference from average	Percentage of average	Percentage of possible duration
	°F.	°F.	°F.	%		%	%
England and Wales ..	88	36	+2·3	63	−6	117	45
Scotland	81	33	+1·5	113	−1	97	27
Northern Ireland ..	76	42	+1·8	81	−2	87	42

RAINFALL OF AUGUST 1949

Great Britain and Northern Ireland

County	Station	In.	Per cent. of Av.	County	Station	In.	Per cent. of Av.
London	Camden Square	1·25	57	*Glam.*	Cardiff, Penylan	2·33	55
Kent	Folkestone, Cherry Gdn.	·95	40	*Pemb.*	St. Ann's Head	2·99	90
,,	Edenbridge, Falconhurst	1·63	62	*Card.*	Aberystwyth	2·94	77
Sussex	Compton, Compton Ho.	1·77	57	*Radnor*	Tyrmynydd	2·84	53
,,	Worthing, Beach Ho.Pk.	2·11	93	*Mont.*	Lake Vyrnwy	3·15	61
Hants	Ventnor, Roy. Nat. Hos.	1·02	51	*Mer.*	Blaenau Festiniog	8·21	73
,,	Bournemouth	·86	34	*Carn.*	Llandudno	2·13	76
,,	Sherborne St. John	1·75	72	*Angl.*	Llanerchymedd	2·94	81
Herts.	Royston, Therfield Rec.	1·36	53	*I. Man.*	Douglas, Borough Cem.	3·28	86
Bucks.	Slough, Upton	1·54	71	*Wigtown*	Port William, Monreith	2·55	66
Oxford	Oxford, Radcliffe	1·48	65	*Dumf.*	Dumfries, Crichton R.I.	2·53	63
N'hant.	Wellingboro', Swanspool	·95	40	,,	Eskdalemuir Obsy.	3·68	71
Essex	Shoeburyness	1·16	66	*Roxb.*	Kelso, Floors	2·17	74
Suffolk	Campsea Ashe, High Ho.	·93	47	*Peebles*	Stobo Castle	2·69	76
,,	Lowestoft Sec. School	·78	35	*Berwick*	Marchmont House	2·50	76
,,	Bury St. Ed., Westley H.	1·54	59	*E. Loth.*	North Berwick Res.	2·21	70
Norfolk	Sandringham Ho. Gdns.	2·32	86	*Midl'n.*	Edinburgh, Blackf'd. H.	3·33	104
Wilts.	Bishops Cannings	1·61	52	*Lanark*	Hamilton W. W., T'nhill	3·98	116
Dorset	Creech Grange	1·09	38	*Ayr*	Colmonell, Knockdolian	3·40	85
,,	Beaminster, East St.	1·83	58	,,	Glen Afton, Ayr San	3·66	68
Devon	Teignmouth, Den Gdns.	1·10	49	*Bute*	Rothesay, Ardencraig	5·38	110
,,	Cullompton	2·35	77	*Argyll*	L. Sunart, Glenborrodale	8·82	155
,,	Barnstaple, N. Dev. Ath.	1·93	58	,,	Poltalloch	4·97	101
,,	Okehampton, Uplands	3·36	79	,,	Inveraray Castle	7·17	109
Cornwall	Bude, School House	1·63	58	,,	Islay, Eallabus	5·43	125
,,	Penzance, Morrab Gdns.	1·68	53	,,	Tiree	3·87	92
,,	St. Austell, Trevarna	1·71	47	*Kinross*	Loch Leven Sluice	3·62	95
,,	Scilly, Tresco Abbey	1·72	63	*Fife*	Leuchars Airfield	3·02	98
Glos.	Cirencester	1·50	50	*Perth*	Loch Dhu	6·53	97
Salop.	Church Stretton	1·87	56	,,	Crieff, Strathearn Hyd.	3·32	79
,,	Cheswardine Hall	1·70	51	*Perth*	Pitlochry, Fincastle	2·90	82
Worcs.	Malvern, Free Library	1·27	44	*Angus*	Montrose, Sunnyside	4·08	146
Warwick	Birmingham, Edgbaston	2·11	78	*Aberd.*	Braemar	3·06	90
Leics.	Thornton Reservoir	1·79	64	,,	Dyce, Craibstone	4·63	153
Lincs.	Boston, Skirbeck	2·02	85	,,	Fyvie Castle	5·64	177
,,	Skegness, Marine Gdns.	2·35	96	*Moray*	Gordon Castle	6·39	202
Notts.	Mansfield, Carr Bank	1·90	68	*Nairn*	Nairn, Achareidh	4·51	186
Derby	Buxton, Terrace Slopes	2·77	63	*Inv's*	Loch Ness, Foyers	..	..
Ches.	Bidston Observatory	1·72	56	,,	Glenquoich	11·10	135
Lancs.	Manchester, Whit. Park	2·68	78	,,	Fort William, Teviot	9·08	146
,,	Stonyhurst College	3·74	74	,,	Skye, Duntuilm	6·58	148
,,	Blackpool	2·65	74	*R. & C.*	Ullapool	3·87	113
Yorks.	Wakefield, Clarence Pk.	1·97	76	,,	Applecross Gardens	8·04	170
,,	Hull, Pearson Park	1·70	58	,,	Achnashellach	8·24	131
,,	Felixkirk, Mt. St. John	2·43	85	,,	Stornoway Airfield	3·22	85
,,	York Museum	1·76	70	*Suth.*	Lairg		
,,	Scarborough	1·72	62	,,	Loch More, Achfary	8·31	142
,,	Middlesbrough	1·98	72	*Caith.*	Wick Airfield	3·94	143
,,	Baldersdale, Hury Res.	1·63	47	*Shetland*	Lerwick Observatory	2·58	86
Norl'd.	Newcastle, Leazes Pk.	2·03	72	*Ferm.*	Crom Castle	2·75	66
,,	Bellingham, High Green	2·80	79	*Armagh*	Armagh Observatory	3·03	84
,,	Lilburn Tower Gdns.	1·93	68	*Down*	Seaforde	3·94	105
Cumb.	Geltsdale	2·17	53	*Antrim*	Aldergrove Airfield	2·70	75
,,	Keswick, High Hill	3·13	60	,,	Ballymena, Harryville	2·93	69
,,	Ravenglass, The Grove	3·83	84	*L'derry*	Garvagh, Moneydig	3·00	77
Mon.	Abergavenny, Larchfield	1·46	49	,,	Londonderry, Creggan	3·76	81
Glam.	Ystalyfera, Wern House	4·90	79	*Tyrone*	Omagh, Edenfel	2·91	68

CLIMATOLOGICAL TABLE FOR THE BRITISH COMMONWEALTH, APRIL 1949

Stations	Pressure: Mean of day M.S.L.	Pressure: Diff. from normal	Temperatures: Absolute: Max.	Temperatures: Absolute: Min.	Temperatures: Mean values: Max.	Temperatures: Mean values: Min.	Temperatures: Mean values: ½ Max. and Min.	Temperatures: Mean values: Diff. from normal	Temperatures: Mean values: Wet bulb	Relative humidity	Mean cloud amount	Precipitation: Total	Precipitation: Diff. from normal	Precipitation: Days	Bright Sunshine: Daily mean	Bright Sunshine: Percentage of possible
	mb.	mb.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	%	oktas	in.	in.		hr.	%
London, Kew Observatory	1017·1	+3·7	78	32	59·4	44·2	51·8	+4·1	47·1	68	5·0	1·46	+0·01	12	7·0	51
Gibraltar	1017·8	+1·4	82	51	69·4	57·7	63·5	+2·6	58·9	76	4·8	2·54	—	9	6·8	52
Malta	1019·9	+6·5	76	45	67·5	54·1	60·8	−0·1	58·0	67	2·9	0·16	—	2	10·2	78
St. Helena	1015·0	−0·4	76	60	72·3	63·2	67·7	+3·0	63·5	98	7·5	4·28	+0·81	21	—	—
Lungi, Sierra Leone	1011·4	—	98	72	88·3	76·1	82·2	—	75·7	78	4·7	2·38	—	6	7·6	63
Lagos, Nigeria ..	1006·2	−3·2	95	70	91·4	74·6	83·0	+0·2	79·1	78	6·6	2·88	—	6	6·7	55
Kaduna, Nigeria ..	1007·5	—	100	62	94·3	72·5	83·4	+1·2	72·7	59	5·2	1·76	−1·32	2	7·8	63
Chileka, Nyasaland	1016·8	+0·3	88	58	80·8	63·3	72·1	+0·3	65·1	72	3·7	0·81	−0·59	10	7·0	60
Lusaka, Rhodesia ..	1014·7	+0·5	87	54	82·2	58·7	70·5	+1·6	62·3	73	2·1	0·86	+0·10	1	9·9	85
Salisbury, Rhodesia	1016·7	+0·2	83	46	79·5	53·6	66·5	+0·6	58·0	67	1·9	0·46	−0·61	3	8·5	73
Cape Town	1017·8	+1·4	85	49	72·2	54·9	63·5	+0·3	54·3	76	4·3	2·49	+0·62	13	—	—
Palmietfontein, S. Africa	1019·9	—	80	33	76·0	46·2	61·1	—	50·5	66	1·0	1·22	—	4	9·6	—
Mauritius																
Calcutta, Alipore Obsy	1006·8	+0·4	96	68	91·7	75·8	83·7	−1·9	77·3	74	4·6	6·00	+3·82	11	8·7	69
Bombay	1008·9	+0·1	94	73	90·6	77·6	84·1	+1·0	76·5	71	1·7	0·00	−0·05	0	9·6	76
Madras	1008·2	−0·2	108	77	96·1	80·2	88·1	+2·8	78·1	69	4·6	0·91	+0·28	3	9·9	80
Colombo, Ceylon ..	1009·8	+1·1	90	71	87·2	74·7	80·9	−1·8	76·3	84	4·7	22·98	+13·25	14	7·6	62
Singapore	1009·8	+0·9	94	73	88·4	75·3	81·9	+0·3	76·8	83	6·1	9·47	+1·84	19	—	—
Hongkong	1014·6	+2·0	87	59	75·7	66·8	71·3	+0·5	67·2	83	—	5·21	−0·44	12	4·1	32
Sydney, N.S.W. ..	1022·6	+4·2	87	49	69·9	54·7	62·3	−2·4	57·1	75	4·1	1·24	−4·28	12	6·3	56
Melbourne	1022·5	+3·0	81	38	64·9	48·1	56·5	−3·0	51·4	74	6·0	1·19	−0·98	12	4·7	42
Adelaide	1023·4	+3·6	85	45	72·0	52·6	62·3	−1·6	—	—	3·0	0·22	−1·50	9	6·7	60
Perth, W. Australia	1017·5	−0·9	96	49	81·2	59·0	70·1	+3·3	61·2	54	4·1	1·91	+0·26	11	6·5	58
Coolgardie	1019·3	+1·0	93	41	79·0	54·0	66·5	+1·5	54·0	41	2·8	0·00	−0·96	0	—	—
Brisbane	1020·4	+2·8	88	52	76·1	59·2	67·7	−2·6	61·1	67	3·6	0·63	−3·14	7	7·4	64
Hobart, Tasmania ..	1019·0	+4·2	74	35	61·4	43·5	52·5	−2·7	46·3	65	5·0	1·06	−0·79	8	6·1	56
Wellington, N.Z. ..	1011·3	−5·8	68	40	59·2	47·7	53·5	−2·3	50·6	80	5·1	4·85	+0·97	16	5·5	50
Suva, Fiji	1011·0	+0·4	89	68	84·4	73·2	78·8	+0·2	76·2	88	6·2	25·09	+12·88	22	4·8	41
Apia, Samoa ..	1010·8	+1·1	89	72	88·0	75·4	81·7	+1·5	78·8	79	4·7	7·00	−2·77	23	8·5	72
Kingston, Jamaica ..	1014·8	+0·7	94	67	88·2	72·0	80·1	+1·7	73·0	67	2·0	0·21	−1·03	3	9·7	78
Grenada, W. Indies	—	—	91	70	87·0	73·0	80·0	+1·1	74·0	74	4·0	1·26	−0·90	12	—	—
Toronto	1014·4	−1·7	75	28	54·2	37·5	45·9	+3·8	36·0	66	5·3	1·15	−1·14	9	6·4	48
Winnipeg	1014·4	−2·3	88	15	53·1	32·2	42·7	+5·0	32·2	80	5·6	0·08	−1·32	4	7·4	54
St. John, N.B. ..	1011·6	−1·8	58	28	50·0	34·4	42·2	+3·2	37·7	82	8·0	3·70	+0·19	15	5·2	39
Victoria, B.C. ..	1018·8	+1·3	64	31	55·3	39·0	47·1	−0·8	40·2	86	6·4	1·41	−0·11	12	6·7	49